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REVIEW ARTICLE

STRETCHING TO REDUCE WORK-RELATED MUSCULOSKELETAL DISORDERS: A SYSTEMATIC REVIEW

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Both authors contributed equally to this paper.

Objective: This article reviewed the literature to clarify the physiological effects and benefits of, and misconceptions about, stretches used to reduce musculoskeletal disorders.

Methods: Nine databases were reviewed to identify studies exploring the effectiveness of stretching to prevent work-related musculoskeletal disorders. Included studies were reviewed and their methodological quality was assessed using the PEDro scale.

Results: The physiological effects of stretches may contribute to reducing discomfort and pain. However, if other measures are not in place to remediate their causes, stretches may suppress awareness of risks, resulting in more debilitating injuries. If inadequately performed, stretches may also cause or aggravate injuries. Careful analysis and stretching program design are required before implementing stretches. Seven studies evaluating the effectiveness of stretching to prevent musculoskeletal disorders in different occupations were identified and reviewed.

Conclusion: The studies provided mixed findings, but demonstrated some beneficial effect of stretching in preventing work-related musculoskeletal disorders. However, due to the relatively low methodological quality of the studies available in the literature, future studies are necessary for a definite response. Future studies should minimize threats to internal and external validity, have control groups, use appropriate follow-up periods, and present a more detailed description of the interventions and worker population.

Key words: injury, stretching, work, prevention.

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INTRODUCTION

Musculoskeletal disorders (MSD) are injuries or dysfunctions affecting muscles, bones, nerves, tendons, ligaments, joints, cartilages and spinal discs. MSD include sprains, strains, tears and connective tissue injuries (1, 2). In the US alone, more than 600,000 workers have MSD resulting in days away from work each year (3). It was estimated that the cost of MSD in the US, in 1995, was approximately \$215 billion (4). MSD may occur

as a result of overexertion, cumulative load, contact of body parts with equipment or furniture, or as a result of falls. Activity demands can cause or aggravate MSD (5). Physical load is influenced by the task, environment, tools and devices, and by personal characteristics. Awkward, repeated and prolonged postures, overstretching movements, high repetition or forces can overload the tissues and exceed their threshold of tolerable stress, resulting in MSD (6). Maintenance of static exertion for prolonged time compresses veins and capillaries inside the muscles, causing micro-lesions due to the absence of oxygenation and nutrition. All of these factors can cause imbalance, fatigue, discomfort and pain due to disruption of tissues.

Several interventions are proposed to reduce work-related MSD rates, including work adjustments, re-engineering type modifications, training in ergonomic principles, exercise programs and smoking cessation campaigns (7). There is some evidence for the effectiveness of strengthening exercises in reducing work-related MSD (8–9). There is also a growing interest in, and use of, stretching exercises to reduce the risk of work-related MSD. However, little is known about the specific outcomes of stretching programs. This article presents a review of the literature to clarify the physiological effects and benefits of, and misconceptions about, stretching as a potential way for reducing the rates of work-related MSD.

Physiological effects of stretching

Several physiological effects of stretching have been reported (10–12). In the following sections, we present and comment on previous studies on this topic. We did not include studies into the effects of stretches sustained for very long periods of time (days) because they are not feasible or applicable in the workplace (11).

Viscoelastic changes in the muscle-tendon unit and range of motion. Elastic property refers to the capability of the muscle-tendon unit to return to its original length after being stretched (12). However, an elastic structure immediately returns to its original length after the stretch is released. This does not occur with the muscles because of their viscous properties, which explain why muscles stretch slowly when placed under stress and return to their original length slowly when the stress is removed. However, if a stretch is sustained for prolonged time, or if there is insufficient recovery before a new stretch, the muscle-tendon unit does not return to its original length. In

addition, the muscle will continue to stretch over a finite period of time even if the load is the same (creep) (13). By sustaining a stretch for 30 sec (neither frequency nor longer duration affected the outcome), the muscle compliance increases (14). Muscle stiffness is equal to the length change that occurs, divided by the force applied. Changes in the viscoelastic properties of the muscle-tendon unit due to stretches may explain range of motion (ROM) gains.

Analgesic effect and ROM. Another possible explanation for increased ROM is the analgesic effect of stretching (12). Muscle stretching increases the pain threshold (15). Increased ROM following stretching may be due to analgesic effects. In a study, subjects stretched until they reached their pain threshold (10). On a second stretch, more force was needed to reach the pain threshold and there was increased pain-free ROM. It was argued that if the viscoelastic properties of the muscle had changed, then the same or less force would be required to reach the new pain-free ROM. The authors related the gain in ROM to an increased pain threshold rather than changes in the viscoelastic properties, but they did not suggest an explanation for this mechanism.

Anti-inflammatory effect. Delayed muscle soreness is due to micro-injuries of muscle fibers, resulting from unfamiliar and mainly eccentric exercises (16). Micro-injuries lead to inflammation, swelling and free radical proliferation, causing pain that peaks 24–48 h after exercise and stops within 96 h (16). Stretching is commonly used after physical activity to prevent delayed muscle soreness. Despite this, there is an extensive amount of studies showing that stretching is not effective in preventing delayed muscle soreness after intense activities (16, 17).

Neurophysiological changes and ROM. Neurophysiological effects were considered as a possible reason for increased ROM following stretching (18). Proprioceptive neuromuscular facilitation (PNF) stretches are based on the belief that a muscle contraction would cause a reciprocal inhibition allowing a larger stretch. However, it was found that reciprocal inhibition does not occur (19, 20). In fact, it was observed that the electrical activity of muscles stretched using PNF was increased (19).

Muscle contraction changes. Stretches are commonly performed prior to strength and power activities to prevent muscle injury and soreness (21). However, many studies have shown detrimental effects of stretching in strength and power performance, and there is a lack of evidence about stretching to prevent injury in strength and power activities (22). It seems reasonable to recommend eliminating the practice of stretching prior to these activities. The findings of the review of Rubini et al. (21) support the findings reported by Young & Behm (22). They reported that strength performance was impaired independently of which stretching technique (i.e. static, ballistic or PNF) was used. They reported that decreases in strength ranged from 4.5% to 28%, regardless of the type of contraction being tested (i.e. isometric, isotonic or isokinetic). Thus, they concluded, stretching may be contra-indicated for workers performing jobs

where strength and power activities are typical characteristics of the tasks, such as firefighters, emergency service workers, and heavy palletizing work.

On the other hand, myofascial pain syndromes are related to decreased blood flow in the muscles due to sustained contraction for prolonged periods of time (23). Stretching results in more efficient muscle contraction requiring less oxygen (12). However, it is not known how long a stretch should be sustained for this purpose. Moreover, this effect has only been shown immediately after stretching but not as a long-term effect (12). Despite, these findings suggest that stretching may be indicated for workers performing jobs where continuous sustained contraction (i.e. isometric contraction) is typical of the activities performed (e.g. precision work such as computer panel assembly and data entry), unless the forces required are high (e.g. wire welding) given the decreases in force generation capabilities

Interaction between the physiological effects of stretching. Combined changes in neurophysiologic and viscoelastic properties might negatively affect muscle contraction (21). Decreased sensitivity of muscle spindles, and inhibition of α motoneuron due to activation of nociceptors, type III and IV joint receptors, and Golgi tendon organs, may be responsible for inhibition of the muscle fibers following stretching. Conversely, some studies reported an increased or unaltered electromyographic activity following stretching attributed to the increased ROM due to analgesia (19, 20).

Tendons stretch from 1% to 2% when load is applied (muscle contraction). After the contraction, the tendon returns to its initial length. However, tendons stay elongated by about 1% (residual strain) after contractions without recovery or sustained for a prolonged time (13). Tendons have reduced stress tolerance capacity due to residual strain (decreased cross-sectional area). Also, increased muscle compliance due to stretching may limit crossbridge coupling decreasing force production capabilities (21). Muscle and tendon alterations modify mechanical efficiency requiring increased contraction to generate the same force. Similar changes may be observed in other musculoskeletal tissues due to their viscoelastic characteristics.

METHODS

Literature search and evaluation

To identify studies using stretches to prevent work-related MSD, 9 electronic databases were searched (AMED, Cinahl, EMBASE, Medline, PASCAL, PubMed, Scopus, Science Direct, and Web of Science databases) from inception to November 2007. The search strategies combined terms for “injury”, “work”, “stretching exercises” and “prevention”. Search strategies were created specifically for each database (see Appendix I). We created more sensitive, and thereby less specific, search strategies due to the low number of hits per database using a more specific search. The authors independently screened all titles and abstracts identified and acquired the full-text publication of all potentially eligible studies. The bibliographies of all retrieved studies were screened for additional relevant articles. Experts in the topic, including the Cochrane Musculoskeletal Group and the Cochrane Injuries Group, were contacted in an effort to identify further published, unpublished or ongoing studies pertinent to this review.

To be eligible, studies had to: (i) investigate the use of stretching to prevent work-related MSD; (ii) have a group receiving only stretching as intervention; (iii) be peer-reviewed; (iv) be published in English; and (v) be published in full-text. Studies that only used stretching combined with other interventions were not eligible, since in these studies the specific effects of stretching cannot be evaluated given the multiple interventions and confounders. Both authors applied independently and in duplicate the eligibility criteria to the methods section of each potentially eligible study. Finally, both authors extracted data independently and in duplicate, using a standardized form.

Assessment of the methodological quality of the studies

Lack of time for retrieving and interpreting research is the main reason why practitioners do not implement evidence into their practices (24). We summarized previous research findings and assessed the methodological quality of the studies to assist professionals in their decision about whether to implement stretching in the workplace to help prevent MSD. The methodological quality of the studies was assessed using the PEDro scale (25). The items in this scale were chosen by a panel of experts based on two other scales developed by formal scale development techniques (Jadad scale and Delphi list). The reason why the PEDro scale was chosen, as opposed to one of the two other scales mentioned or any other of the many scales available, is because it offers a more thorough assessment of methodological quality of applied studies, and it has been reported to be a reliable tool for the assessment of the methodological quality of studies.

RESULTS

The database search yielded 334 references. Few studies focused on stretches to prevent work-related MSD; most focused on stretches to prevent sport-related injuries, and relevant information from those studies was included in the physiological effects and discussion sections. Title and abstract screening resulted in 34 potentially eligible studies.

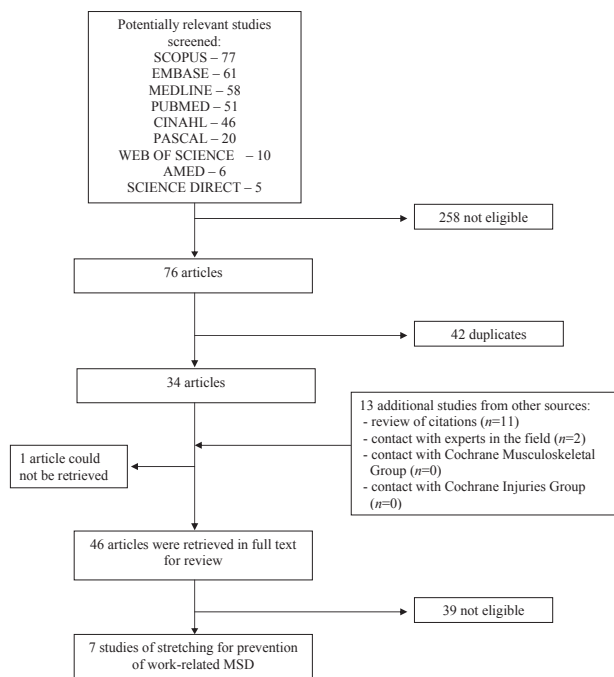


Fig. 1. Stages of systematic review of studies investigating the use of stretching to reduce work-related musculoskeletal disorders.

The chance-adjusted between-reviewer agreement on the application of study inclusion criteria to study titles and abstracts was excellent ($\kappa = 1.00$). Thirteen additional potentially eligible studies were identified from bibliographic searches and contact with content experts (Fig. 1). After a detailed review of the potential 46 studies, only 7 fulfilled the inclusion criteria. Table I presents the results of the methodological quality assessment using the PEDro scale for the included studies. Table II provides an overview of the included studies, including the group of workers investigated, types of stretching and stretching protocol used, main findings in relation to the effectiveness of the stretching programs, and limitations of the study. These studies were grouped and are discussed on the next sections according to the occupational activities evaluated.

Stretches in computer work. The study by Trujillo & Zeng (26) evaluated a computer-based break reminder program ("Stop and Stretch") to prevent MSD due to prolonged computer usage. According to the authors, the hand and wrist stretches "help relax tense muscles, improve blood circulation, increase the person's ROM and prevent cumulative trauma disorders" (p. 115). Nineteen computer users completed a survey about the program one month after installation. In relation to MSD, 53% (10) of the subjects reported fewer symptoms and all participants reported they found it was helpful. Moreover, 63.3% (12) of the subjects reported that the program had a positive effect on their productivity. However, from the data

Table I. Quality scores and criteria list for the methodological assessment of reviewed articles

Study	Scores on PEDro scale*											Total score†
	1	2	3	4	5	6	7	8	9	10	11	
Hilyer et al., 1990 (30)	+	-	-	-	-	-	-	+	-	+	-	3/11
Henning et al., 1997 (28)	+	-	-	-	-	-	-	-	+	+	-	3/11
Moore, 1998 (29)	+	-	-	-	-	-	-	-	+	-	+	3/11
Saltzman, 1998 (27)	-	-	-	-	-	-	-	-	+	-	-	1/11
Hartig & Henderson, 1999 (32)	+	-	-	-	-	-	-	-	+	+	+	4/11
Amako et al., 2003 (31)	+	+	-	-	-	-	-	-	-	+	+	4/11
Trujillo & Zeng, 2006 (26)	-	-	-	-	-	-	-	+	+	-	+	3/11

+ the criterion was clearly satisfied; - the criterion was not clearly satisfied; †The total score is determined by counting the number of criteria that are satisfied.

*Column numbers correspond to the following criteria on the PEDro scale:

1: description of the source of subjects and inclusion and exclusion criteria; 2: random allocation of subjects to groups; 3: concealment of allocation; 4: the groups were similar at baseline regarding the most important prognostic indicators; 5: all subjects were blinded; 6: all therapists who administered the therapy were blinded; 7: all assessors who measured at least one key outcome were blinded; 8: measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups; 9: all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"; 10: the results of between-group statistical comparisons are reported for at least one key outcome; 11: the study provides both point measures and measures of variability for at least one key outcome.

Table II. Overview of studies investigating the use of stretching exercises to prevent work-related musculoskeletal disorders (MSD)

Reference	Occupational task assessed	Stretching protocol	Main findings	Limitations
Trujillo & Zeng, 2006 (26)	Computer work	Use of computer program ("Stop and Stretch") to remind and guide workers through stretching exercises	63.3% of the subjects reported that the program had a positive effect on their productivity, 53% of the subjects reported fewer symptoms, and all participants reported they found it was helpful	No control group; limited description of stretching protocol
Saltzman, 1998 (27)	Computer work	Use of a computer program ("Stretch Break") to remind and guide workers through a set of stretching exercises that were performed after every 45 min of work, and lasted between 1 and 2 min	Subjects who used this software program reported that it was effective in lowering their stress level and in reducing stiffness and muscle ache associated with long hours at the keyboard	No control group; limited description of stretching protocol
Henning et al., 1997 (28)	Computer work	The authors suggested that workers performed 5 stretching exercises per hour and that each stretching exercise was held for 15 sec	Productivity and body discomfort significantly improved in computer operators performing short rest periods with stretching exercises compared with short rest periods only or control (no intervention)	Carryover effect may have overestimated stretching effectiveness to prevent MSD
Moore, 1998 (29)	Manufacturing work	Stretching sessions were held 5 times a day and lasted 5–8 min	Subjects reported improvement on both flexibility and physical self perception – increased perceptions of their body attractiveness, physical conditioning, and overall self worth	No control group; limited description of stretching protocol
Hilyer et al., 1990 (30)	Heavy work (firefighters)	The stretching exercise program consisted of a 30-min session held approximately 3 times a week during a period of 6 months	Flexibility training had a beneficial effect on reducing the severity and costs of MSD in firefighters	Limited description of stretching protocol
Amako et al., 2003 (31)	Heavy work (military recruits)	Stretching exercises were sustained for 30 sec. Stretching exercise sessions took 20 min to be completed and were carried out before and after physical training sessions	Subjects who performed stretching exercises had a significantly lower incidence of muscle/tendon injury and low back pain compared with subjects who did not perform stretching exercises	Control group also performed stretching for around 5 to 10 min before each training session, which may have confounded results
Hartig & Henderson, 1999 (32)	Heavy work (military recruits)	Four stretching sessions per day, with 1 hamstring stretching exercise, which was held for 30 sec and repeated 5 times per session	Subjects who performed stretching exercises showed a significant decrease in occurrence of lower extremity overuse injuries and a significant increase in range of motion compared with subjects who did not perform stretching exercises	Results may have been confounded by performance of stretching exercises in single leg stance

presented it is not possible to say if the improvement was due to the stretches or due to the systematic introduction of rest breaks during computer work. Furthermore, the authors did not describe the stretching protocol used in their study (i.e. which stretching exercises were used, at what frequency, and for how long each stretch was held).

Saltzman (27) also reported that the use of a computer program ("Stretch Break") to encourage stretching had a positive effect on the prevention of MSD. Stretching sessions lasting 1–2 min were performed after every 45 min of work. The author stated that "computer operators who used this software program with its frequent short stretching breaks reported that it was effective in reducing stiffness and muscle ache associated with long hours at the keyboard. They also credited the program with lowering their stress level (p. 4). However, it was not possible to determine if the reported improvement was due to stretching or due to rest breaks only. Moreover, it is not described which

stretching exercises were used, to which body parts they were applied, or for how long each stretch was performed.

Another study reported that productivity and body discomfort improved significantly in 19 computer operators (claim processors) taking short rest periods with stretching compared with short rest periods only or control (no intervention) (28). Six different stretches were applied to the following body parts: (i) fingers, hands, and forearms; (ii) fingers and wrists; (iii) chest, shoulders, and upper back; (iv) shoulders and neck; (v) both sides of the trunk; and (vi) lower back. The workers performed 5 stretches per hour and each stretch was held for 15 sec. It was up to the workers which body part they were going to stretch. Individuals in the short rest periods plus stretching group reported on a 5 point-scale (lower values meaning higher comfort) higher levels of leg and feet (1.4) and eye (1.7) comfort compared with the other 2 groups (1.8, 2.1 and 1.8, 2.2, respectively, for the short rest and control groups).

Interestingly, productivity (calculated as the number of claims processed per hour) was also higher (15%) in this group. The authors stated that “frequent rest breaks can improve the safety and health of workers performing computer-mediated work with little risk of productivity loss” (p. 87). However, carryover effect may have occurred, since the study used a non-randomized repeated treatment design. That is, although the significant positive results were observed after the short rest periods with stretching intervention, this was the last 1 of the 3 interventions to be implemented sequentially; thereby positive results could have occurred due to a cumulative effect resulting from previous interventions.

Stretches in manufacturing work. Moore (29) implemented a stretching program including 36 sessions over a 2-month period to 60 employees of a pharmaceutical manufacturing plant. The stretching sessions were held 5 times a day and lasted 5–8 min. The stretching exercises involved the neck, shoulder, arm, trunk, hip, back and legs. After the completion of the stretching program, there was an improvement in both flexibility ($p < 0.001$) and physical self perception – increased perceptions of their body attractiveness ($p < 0.001$), physical conditioning ($p < 0.05$) and overall self worth ($p < 0.05$). During the program period there were no reported MSD. The author concluded that the implementation of a stretching program in the workplace can potentially decrease work-related MSD due to increases in flexibility. However, stretching exercises were not fully explained so that the study could be replicated. Moreover, the study did not include a control group, which was a major limitation for the interpretation of the results (e.g. are the changes due to the program or are they just placebo effects, or confounded by other changes in the workplace?).

Stretches in heavy work. Hilyer et al. (30), in a 2-year follow-up study, reported that flexibility training had a beneficial effect on reducing the severity and costs of MSD in firefighters. In this study, they divided 469 firefighters into 2 groups (experimental and control). The stretching exercise program consisted of a 30-min session held every working day in a working schedule consisting of one day on, 2 days off, during a period of 6 months. The time of the day when the stretching exercise sessions were performed (e.g. before, during, or after shift) was variable. Twelve stretching exercises were performed in each session. There was a significant increase ($p < 0.001$) in knee flexion (2.3%), shoulder flexion (0.1%), shoulder extension (6.7%), and sit and reach test (13.4%) for the experimental group after the 6 month stretching program. There was also a significant decrease ($p < 0.001$) in knee flexion (–14.6%), shoulder flexion (–2%), shoulder extension (4.8%), and sit and reach test (–10%) for the control group after the 6 months of work without stretching. There was a non-significant lower incidence of MSD in the experimental group (19.1%) in relation to the control group (23.9%). It was stated that MSD in the experimental group were less severe, thereby resulting in significantly less costs due to lost time (\$950/injury) in relation to the control group (\$2828/injury). Unfortunately, neither stretching exercises nor details about their execution were reported.

Amako et al. (31) reported on the implementation of a stretching program to reduce the incidence of MSD in 901 military recruits. The recruits were divided into experimental and control group. The static stretching exercise program consisted of 18 stretches (4 for the upper extremities, 7 for the lower extremities, and 7 for the trunk), which are demonstrated using illustrations in their article. Each stretch was sustained for 30 seconds, and the complete stretching exercise session took 20 min to complete. Stretching exercise sessions were carried out before and after physical training sessions by the military recruits. The experimental group had lower ($p < 0.05$) incidence of muscle/tendon injury (2.5%) and low back pain (1.0%) compared with the control group (6.9% and 3.5%, respectively). The overall MSD rate was lower but not significantly different ($p = 0.12$) between experimental (11.2%) and control (14.1%) groups. Although not significant, the experimental group also had a lower incidence of ligament injury (2.5%, $p = 0.92$) and joint injury (1.4%, $p = 0.95$) compared with the control group (3.1% and 1.6%, respectively). The authors believe that the lack of significant difference for overall MSD rate between the groups was due to too small a sample size resulting in insufficient statistical power. Furthermore, it was reported that the military recruits in the control group performed “dynamic stretching” (construct not defined by authors) for around 5–10 min before each training session, which may be a confounding factor.

Another study (32) supports the findings of Amako et al. (31). Military recruits participating in a 13-week stretching program experienced a significant decrease in occurrence of lower extremity overuse injuries compared with military recruits who did not participate (32). The stretching program consisted of 4 stretching sessions per day, with one hamstring stretch held for 30 sec and repeated 5 times per session. Lower extremity overuse injuries were reported by 29.1% of the control group and by 16.7% of the experimental group ($p < 0.05$). Knee extension increased 6.5% in the control group and 16.8% in the experimental group ($p < 0.001$). The authors concluded that reduction in lower extremity overuse injuries was due to increased ROM in the experimental group. Hamstring stretches were performed during single-leg stance involving sustained isometric co-contraction and proprioceptive stimulation of the leg. Thus, it cannot be stated that stretching was the only factor responsible for decreased lower extremity overuse injuries in the experimental group, since both strength and proprioceptive training may have helped (33).

DISCUSSION

The established physiological effects of stretching are: ROM gain, short-term relief of discomfort/pain, viscoelastic changes in the tendon-muscle unit, and impaired muscle contraction with decreased peak force. However, a question remains: What physiological changes in the muscle would be related to MSD prevention? For example, it is necessary to consider whether increased ROM is beneficial to different workers from the perspective of MSD prevention. Clearly this discussion will lead to the acknowledgement that increased ROM is of interest

for some workers but not for others. Consequently, stretching exercises will be beneficial for some occupational groups but not for others. It is necessary to investigate which physiological changes are most beneficial to avoid work-related MSD so that stretches can be prescribed accordingly and safely.

All studies reviewed showed positive results towards using stretches to prevent work-related MSD. However, careful consideration should be taken before reaching conclusions. Most studies created their stretching protocols for ROM gain because it is believed that athletes can prevent MSD by performing stretches to improve flexibility (34). Increase in the compliance of the muscle-tendon unit may prevent injuries in athletes performing sports with high intensity of stretch-shortening cycles (34). The same may be applicable to workers in jobs with this characteristic. Indeed, the results reported showed a potentially beneficial effect of stretching for preventing MSD in individuals whose jobs involve a considerable amount of physical activity (e.g. police officers, firefighters, military recruits, sport referees). However, most of the tasks performed in the workplace do not involve high intensity of stretch-shortening cycles.

Studies reported detrimental effects of stretching exercises prior to strength and power activities (21, 22). Considering firefighters perform strength and power activities (35, 36), the beneficial effect of stretching seem to contradict other studies (30). However, the reviews reporting detrimental effects (21, 22) did not include the study reporting beneficial effects (30) because the focus of their reviews was on strength training and not on occupational activities. The different results may be explained by the fact that even though firefighters perform strength and power activities, these tasks represent only one part of their job. Possibly, more time is spent on office work, cardiovascular training and driving. Further evaluation of potential effects of stretching for occupational activities involving combined exposures is required.

The arbitrary use of stretching is controversial because some people are naturally flexible or even hyper-flexible (37). Also, stretching may decrease joint stability and be hazardous for some work tasks. It is uncertain whether ROM gain through stretching occurs due to decreased muscle stiffness or increased laxity of joint passive stabilizers (e.g. ligaments, capsule). If the latter represents the mechanism, then stretching may increase the risk of injury in individuals with joint instability. It has been reported that men with hyper-mobile backs are more likely to develop low back pain (38); thus back and hamstring stretching could be a problem for these individuals.

Due to their analgesic properties (15, 39), stretches might relieve discomfort and break the cycle of discomfort-pain-muscle stiffness-injury pain due to awkward postures, continuous (isometric) or repetitive (isotonic) muscle contractions. This may be one of the reasons for the positive results reported in the studies investigating the use of stretching in the workplace. On the other hand, stretches in isolation may be a problem if the causes of discomfort and potential injury to the musculoskeletal tissues are not modified (e.g. inadequate workstation design requiring awkward posture and excessive

force). Workers may have a false sensation of safety due to the analgesic characteristics of stretches while exposed to these adverse conditions. The analgesic effect of stretching may decrease the sensitivity of endogenous pain-related alertness systems. The optimal functioning of these structures is imperative for the identification and correction of potentially harmful postures and movements in the workplace. Suppressing awareness of risks due to inadequate postures or excessive force may result in injuries.

Stretches may be used to compensate for excessive and/or cumulative characteristics of the work demands, but they should not be used to "allow" the workers to do more or faster work. Stretching programs should not be used as an independent preventative measure for MSD. It is important to highlight that the objective of ergonomics is to make tasks, jobs, products, environments and systems compatible with the needs, abilities and limitations of people, as opposed to making the people "compatible" with the work characteristics and demands (40). In other words, the primary efforts should focus on adaptation of the work characteristics to the workers' abilities and not the adaptation of the workers to the job demands. Stretches may alleviate the problem, but they do not address the causes.

Another factor to consider is the risk of stretching-related injuries or injuries aggravation due to stretches, and time expenditure to stretch. There are 3 different types of stretching: static, PNF and ballistic (41). Ballistic stretching is dynamic, involving fast bobbing or jerky motions imposed on the muscle. This type of stretching is not recommended because it may result in muscle soreness and injury due to its vigorous nature, thus it should not be used in the workplace (41). There is a general belief, but no consensus, that PNF is the most effective stretching technique to gain flexibility; however, PNF is the most time-consuming technique (41). The stretching types should be chosen carefully and indicated so that they do not add to the mechanical loading of the tissues but compensate for mechanical stress. Overloaded tissues need recovery time from work. Work-rest schedules and stretch routines need to be designed carefully. Since there is no consensus about a better technique for increasing flexibility, static stretching seems to be the most appropriate technique because it is safer than ballistic stretching and less time-consuming than PNF. Careful work physical demands analysis and stretching program design are required before implementation.

The use of the PEDro scale to analyze the methodological quality of the studies, demonstrated that none of them followed minimal standards required for randomized controlled trials. One out of the 7 studies reported the use of randomization to assign participants to intervention groups. No study reported blinding, concealment of allocation, or similarity between groups at baseline. All these are required to make assumptions about whether the observed changes in the outcome happened due to the implemented intervention (42). Despite the positive trends towards the benefits of stretching, the studies' limitations limit our ability to reach a definite response about the effectiveness of stretching to prevent work-related MSD. Future studies are required for a better understanding of the relationship

between stretching and musculoskeletal health at work for a definite response to the effectiveness stretching in preventing MSD. Future studies should minimize threats to internal and external validity, include control groups, use appropriate follow-up period, and present a more detailed description of the interventions and worker populations. Moreover, future studies should investigate different stretching protocols, types of stretching (static or PNF), frequency, intensity, duration, and time of stretch (before, after or during work) so that more efficient protocols can be implemented. Finally, future studies should compare the effects of stretching across different occupational groups with distinct demands.

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APPENDIX I. Specific search strategies for each database

I. MEDLINE

Search terms for "injury"

1. injur\$ OR traum\$

Search terms for "stretching"

2. muscle stretching exercise\$ OR dynamic stretching OR isometric stretching OR passive stretching OR relaxed stretching OR static passive stretching OR static active stretching OR active stretching OR ballistic stretching OR proprioceptive neuromuscular facilitation stretching OR static stretching OR stretch\$

Search term for "work"

3. work\$

Search terms for "prevention"

4. preventive measur\$ OR preventive therap\$ OR prophylaxis OR control OR prevent\$

Combination of concepts search terms:

5. 1 AND 2 AND 3 AND 4

II. AMED

Search terms for "injury"

1. injur\$ OR traum\$

Search terms for "stretching"

2. muscle stretching exercise\$ OR dynamic stretching OR isometric stretching OR passive stretching OR relaxed stretching OR static passive stretching OR static active stretching OR active stretching OR ballistic stretching OR proprioceptive neuromuscular facilitation stretching OR static stretching OR stretch\$

Search term for "work"

3. work\$

Search terms for "prevention"

4. preventive measur\$ OR preventive therap\$ OR prophylaxis OR control OR prevent\$

Combination of concepts search terms:

5. 1 AND 2 AND 3 AND 4

III. EMBASE

Search terms for "injury"

1. injur\$ OR traum\$

Search terms for "stretching"

2. muscle stretching exercise\$ OR dynamic stretching OR isometric stretching OR passive stretching OR relaxed stretching OR static passive stretching OR static active stretching OR active stretching OR ballistic stretching OR proprioceptive neuromuscular facilitation stretching OR static stretching OR stretch\$

Search term for "work"

3. work\$

Search terms for "prevention"

4. preventive measur\$ OR preventive therap\$ OR prophylaxis OR control OR prevent\$

Combination of concepts search terms:

5. 1 AND 2 AND 3 AND 4

IV. PASCAL

Search terms for "injury"

1. injur\$ OR traum\$

Search terms for "stretching"

2. muscle stretching exercise\$ OR dynamic stretching OR isometric stretching OR passive stretching OR relaxed stretching OR static

passive stretching OR static active stretching OR active stretching OR ballistic stretching OR proprioceptive neuromuscular facilitation stretching OR static stretching OR stretch\$

Search term for "work"

3. work\$

Search terms for "prevention"

4. preventive measur\$ OR preventive therap\$ OR prophylaxis OR control OR prevent\$

Combination of concepts search terms:

5. 1 AND 2 AND 3 AND 4

V. SCOPUS

Search term for "injury"

1. injur*

Search term for "stretching"

2. stretch*

Search term for "work"

3. work*

Search term for "prevent"

4. prevent*

Combination of concepts search terms:

5. #1 AND #2 AND #3 AND #4

VI. PUBMED

Search terms:

Work: work*

Stretching: stretch*

Injury: injur*

Prevention: prevent*

Combination of concepts search terms:

work* AND stretch* AND injur* AND prevent*

VII. CINAHL

Search terms:

Work: work*

Stretching: stretch*

Injury: injur*

Prevention: prevent*

Combination of concepts search terms:

work* AND stretch* AND injur* AND prevent*

VIII. WEB OF SCIENCE

Search terms:

Work: work*

Stretching: stretch*

Injury: injur*

Prevention: prevent*

Combination of concepts search terms:

work* AND stretch* AND injur* AND prevent*

IX. SCIENCE DIRECT

Search terms:

Work: work*

Stretching: stretch*

Injury: injur*

Prevention: prevent*

Combination of concepts search terms:

work* AND stretch* AND injur* AND prevent*